Head Waves in Asian Marginal Seas

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LONG-TERM GOALS

To develop a robust means to utilize readily-obtained precursor (or head-wave-like) arrival measurements for purposes of geoacoustic inversion. Under certain conditions these arrivals can be classified as *interference head waves*.

These arrivals are important features of shallow water propagation that are exhibited at relatively short ranges (< 1 km). They are more directly linked with seabed properties, in contrast to long-range, trapped modal arrivals.

OBJECTIVES

The objective this year was to further the understanding of interference head waves, specifically in terms of their frequency and amplitude dependence on source and acquisition geometry. This builds on our analysis of precursor arrivals measured from the Yellow Sea as part of the August 1996 joint U.S.-China Yellow Sea Experiment that was published this year [1].

APPROACH

The approach involved revisiting a 1965 work by Chekin [2], along with studies by Červený and Ravindra [3] that first utilized the parameter ζ, which embodies source-to-range, sediment sound speed gradient, and sound frequency.   Combining both works, an analytical expression for the frequency dependence of the interference head wave was derived that is a function of ζ. This expression was tested against simulations using the RAM Parabolic Equation (PE) code.

WORK COMPLETED

The analysis of the frequency dependence of interference head waves was completed for which a better understanding of interference head waves, and how they can be inverted for sound speed and attenuation in the sediment, was achieved. Results were published in the July issue of the *Journal of the Acoustical Society of America.* Some results from this work are summarized below.

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14. ABSTRACT
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15. SUBJECT TERMS

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RESULTS

Figure 1 shows the basic structure of an interference head wave, which can be thought of as the superposition of C_n waves, $n=0,1,2, \ldots$
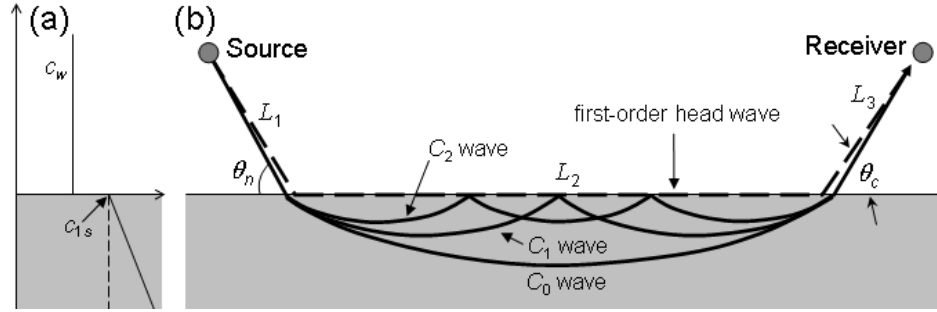

Figure 1. (a) Sound-speed profile in seabed showing constant sound speed, zero gradient (dashed line) and non-zero positive gradient (solid line). (b) Equivalent ray path of a first-order head wave corresponding to the zero gradient case (dashed line) and multiple ray paths (C_n waves) corresponding to the positive gradient case (solid lines). The superposition of the C_n waves constitutes an interference head wave.

The interference head wave propagating through seabed sediment with a linear sound speed gradient is was studied as a function of the parameter ζ, that as mentioned above, is itself a function of frequency f, sediment sound speed gradient, and geometry. For small ζ the spectrum of the interference head wave goes as $|S(f)|/f$, where $S(f)$ is the source amplitude spectrum; as ζ increases the dominant frequency of the spectrum changes to that of the source spectrum. For a range of ζ values, the spectrum may display a shift in dominant frequency. This is illustrated in Fig. 2 that shows the changing behavior of the *received spectrum* of the interference head wave as a function of ζ.

Understanding this basic nature of the interference head wave in terms of its spectral properties, is essential for utilizing such arrivals in geoacoustic inversion. In view of the importance of the parameter ζ, we propose calling it the *Chekin parameter*, to recognize the 1965 work by Chekin [2] from which the parameter can be derived.
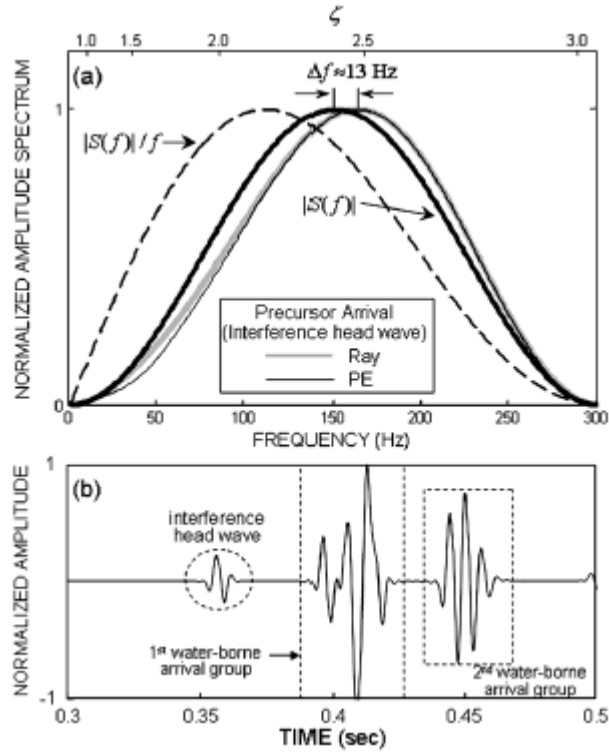
Figure 2. (a) Comparison of the interference head wave amplitude spectrum (thick gray line) predicted from the ray theory approach with that obtained from the PE simulation (thin solid line, and falling nearly entirely within gray line.) The thick solid line is amplitude spectrum of the source, and, for reference, the dashed line represents the amplitude spectrum of a first-order head wave. (b) The PE simulated time series of the interference head wave (within circle) from which the spectrum in (a) is estimated. The two arrival groups arriving after the interference head wave are the water-borne arrivals. The first group consists of the arrivals that have one or fewer interactions with the sea surface; these include the direct, bottom, sea surface, bottom-surface, surface-bottom, and bottom-surface-bottom paths. The second group consists of the arrivals that have interacted with the sea surface twice.

IMPACT/APPLICATIONS

Results of this research will constitute an important contribution to WESTPAC data bases. The technical approach refined in this work can be exploited to obtain geoacoustic bottom properties based on logistically simpler, short range measurements.

RELATED PROJECTS

The work on this project relates to a planned experiment off the Korean coastline, for which the principal organizers are NRL and the Korean Agency for Advanced Development (ADD). The PI and Dr. Choi (now working at Hanyang University in Korea) will participate in this experiment with the goal of obtaining field measurements of interference head waves or related precursor arrivals, from which geoacoustic inversions can be made.

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PUBLICATIONS

J. W. Choi and P. H. Dahl, "Spectral properties of the Interference Head Wave," *J. Acoust. Soc. Am.*, 122 (6), 146-150, July 2007.

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